Journal of Basic and Applied Engineering Research
Print ISSN: 2350-0077; Online ISSN: 2350-0255; Volume 2, Number 4; January-March, 2015, pp. 309-314

http://www.krishisanskriti.org/jbaer.html

An Investigation on Electrochemical Assisted Abrasive Flow Machining Process of Gun-metal by Taguchi Technique

Balinder Chahal[1] and Ravi Gupta[2]

[1]M.Tech Student) Engineering Lovely Professional University
[2]School of Mechanical Lovely Professional University
E-mail: [1]balinderchahal92@gmail.com, [2]raviarya43@gmail.com

Abstract—*Abrasive flow finishing is a modern surface finishing process which come under the categories of nontraditional machining process. This process is used extensively to finish the internal parts of the work piece which are difficult to finish by other finishing process. In abrasive flow finishing, abrasive media moves inside the work piece that helps for material removal and hence finishing. In this paper a research is carried out by clubbing the advantages of two non-conventional machining process i.e. electrochemical assisted abrasive flow finishing process. The main target of this paper is focused on to improve the interior surface quality of gun metal by optimize different process parameters at different level. The experimental design is based on Taguchi technique. To determine the contribution of each parameter, analysis of variance is applied.*

Keywords:-*Abrasive flow finishing (AFF), CFG, Analysis of variance (ANOVA)*

1. INTRODUCTION

Abrasive flow machining is effective advance finishing process used to obtain the better finishing. The need of better surface finishing arises to reduce friction in aerospace and hence torque & fuel economy in engine and eliminating imperfection in medicine.This process is widely used to finish complicated geometry that are not possibleto finish by conventional method. In abrasive flow finishing there are two hollow cylinder which are located in opposite direction and piston move inside each cylinder. In between these two cylinder, a fixture is fixed with the help of screw and nuts. The fixture consists of three parts and inside these parts work piece fixed properly so that abrasive media can flow from lower cylinder to upper cylinder and vice versa. A reduction ratio of 0.95 is provided. In this research electrochemical machining is clubbed with abrasive flow finishing process to obtain the better results as compare to simple electrochemical or abrasive flow finishing.In the recent year a large no. of research carried out in the field of hybrid AFM processes by coupling AFM with aid of other traditional or nontraditional machining processes in order to limitation of high surface roughness and low material removal.Dabrowski et al. [1] studied the developing hybrid process Electrochemical aided abrasive flow machining (ECAFM) using polymeric electrolytes. The experimental evaluation of several solid electrolytes with various bonds has been carried out (the polypropylene glycol (PPG) with the NaI salt share and ethylene glycol PEG with KSCN salt share have been subjected to the tests). B.S. Brar and R.S. Walia [2] study for increasing the material removal and efficiency of abrasive flow machine made hydride process which is combination of abrasive flow machining and electro chemical machining and find the effect of voltage in Electrochemical Assisted Abrasive Flow Finishing Process. Ravi Shankar et al. [3] Helical-Abrasive flow machining process employs a standard helical drill-bit, held between along the axis of the hollow cylindrical work-piece and achieved high material removal rate as compared to AFM process. Material removal rate depend on the diameter of drill bit if diameter of drill bit decrease the material removal rate also increase.Walia et al. [4] study that abrasive flow machine low % improvement in surface roughness increasing efficiency of AFM machine used hybrid process are called centrifugal force assisted abrasiveflow machining. Rotational CFG rod produce centrifugal process into the work piece. Material removal rate and surface finishing is also increase by centrifugal force assisted abrasive flow machining(CFA2FM) process. Singh et al. [5] A set-up developed with combined with abrasive flow machine termed magneto abrasive flow machining (MAFM). Magnetic field applied around work piece for increase the material removal rate and improve surface roughness. Jones and Hull [6] study on ultrasonic flow polishing for achieved good surface and replace mixed ultrasonic energy with abrasive media its results better surface finishing as compare to the abrasive flow machining. Mali and Manna [7] H S Mali and Dr. Manna noted the effect of number of cycle on alloy Al-6063 cylindrical work piece. Das et al. [8] explored a new precision finishing process called magneto-rheological abrasive flow finishing (MRAFF), which is basically a combination of abrasive flow machining (AFM) and magneto-rheological finishing (MRF), developed for Nano finishing of parts even with complicated geometry for a wide range of industrial applications. Mark and Ghose [9] suggest that if oil is mixing in the polymer and abrasive oil breaks the chain of polymer that easily or proper mixing of polymer and abrasive. Abrasive media not stick with work piece when use the abrasive gel in media. Jain and Adsul [10] reported that initial surface roughness and hardness of the work piece are important parameters affecting the material removal rate in abrasive flow machining. Loveless [11] studied on surface finish the effect of viscosity of media. They found that viscosity is the only parameter which significantly affects the surface finish. They found the relationship between initial surface finish and percentage improvement in surface finish is non-linear. Przylenk[12] described that with small bore diameter of work piece, more grains comes in contact with the surface, hence improves surface finish. Williams and Rajurkar [13] study that pressure and media viscosity must important parameter to determine both material removal rate and surface roughness. Researcher achieved that first few cycle improved the surface finish of work piece if another parameter is constant. Petri et al. [14] developed a predictive process modeling system for the abrasive flow machining process that relates the critical parameters using strictly empirical techniques, namely neural networks.

2. ELECTROCHEMICAL ASSISTED ABRASIVE FLOW FINISHING PROCESS (ECA2FM)-

Electrochemical aided abrasive flow finishing process is a hybrid process consist of electro chemical and abrasive flow finishing process. In this process the media consists of mixture of aluminum oxide (Al2O3) particle, silicon based polymer, hydrocarbon gel with sodium chloride (Nacl) salt. Polymer to gel ratio (1:1) has been kept constant for effective finishing. The specific deign of fixture which was made up of nylon shown in Fig. 1. This fixture consists of two copper electrode directly inter connected with workpiece and tool shown in figure2. A D.C power source was used to prevent interruption and for required voltage input as shown in Fig. 3.The electrode rod which is connected to triangular rod acting as cathode or other electrode which is connected to workpiece acting as anode. The fixture is fixed between two hollow cylinders which are located opposite in direction. The electrolytic laden media passes through the annular space between the workpiece and toolresults in better finishing due to combination of two process as compare to simple abrasive flow finishing process.During electrochemical machining, following reaction are take place at anode and cathode. The electrolyte used is Nacl in the abrasive media. The continuous flow of ions are responsible for current and hence ECM.Here workpiece made up of gun metal acts as an anode and when the current applied to it, ionization starts.

$$Zn \rightarrow Zn{+}{+} + 2e{-}$$

While copper and tin present in the alloy remains until all the zinc depleted from work piece internal cylindrical surface. This was due to the place of Tin and copper is at lower position than of zinc in the standard electrochemical series .After depletion of all zinc the ionization of Tin and then copper in the workpiece acts as an anode takes place i.e.

$$Sn \rightarrow Sn^{++} + 2e^{-}$$

$$Cu \rightarrow Cu^{++} + 2e^{-}$$

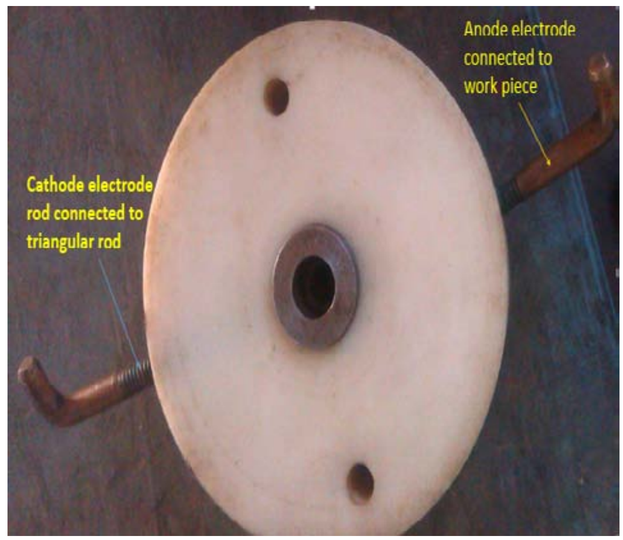


Fig. 1:- Nylon fixture

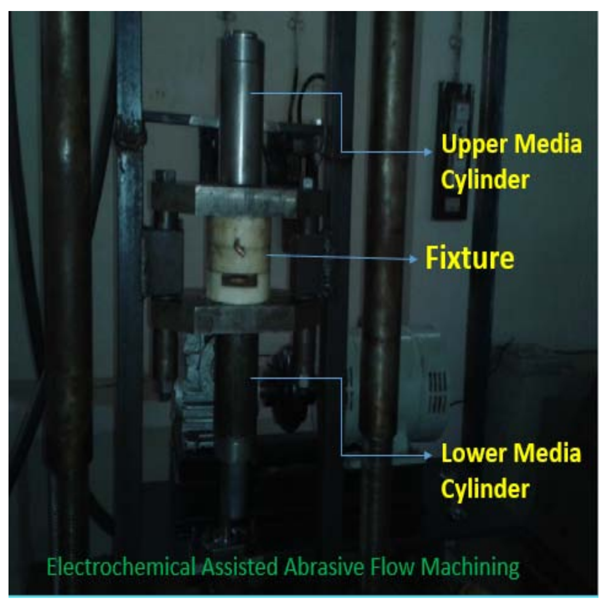


Fig. 2:- Electrochemical Assisted Abrasive Flow Finishing Process

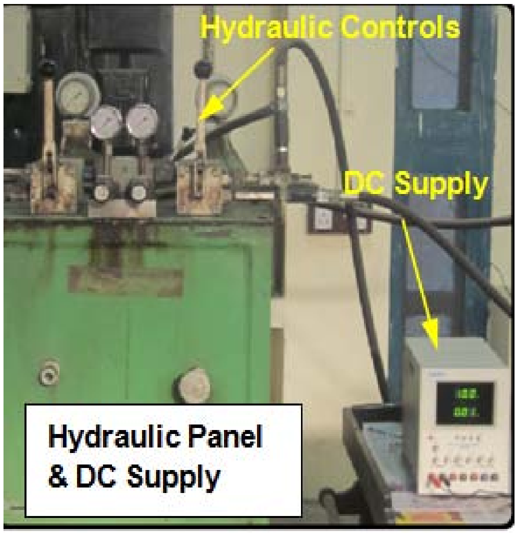


Fig. 3:- Hydraulic Panel and DC Supply

3. EXPERIMENTATION-WORK

The percentage change in surface roughness value is calculated as:

$$\Delta Ra = \frac{\text{Initial Roughness} - \text{final roughness}}{\text{Initial roughness}} * 100$$

The surface roughness (Ra) was depicted by Mitutoyo SJ-201 surface roughness testing machine as shown in figure4.

For experimental design, L9 (34) orthogonal array based on taguchi methodology was used. All process parameter has been studied at three levels. To measure the effect of each parameter, analysis of variance was performed for both S/N and Raw data. The ΔRa is higher the better type quality characteristics, So signal to noise(S/N) ratio was calculated by this formula:

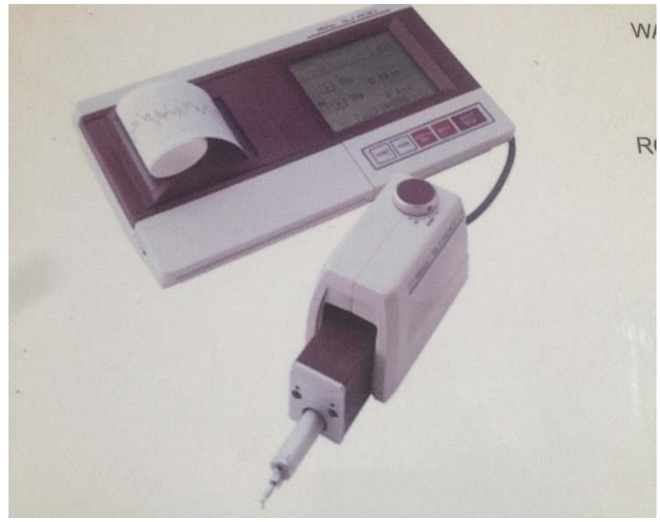


Fig. 4: Surface roughness testing machine(Mitutoyo SJ-201)

$$\left(S/N\right)_{HB} = -10 \log\left(MSD_{HB}\right)$$

Where

$$MSD_{HB} = \frac{1}{R} \sum_{j=1}^{R} \left(1/y_j^2\right)$$

MSD represents mean square deviation, which presents the average squares of all deviations from the target value rather than around the average value.

R = Number of repetitions, y = response value

Table 1: Process parameters value at different level

S No	Parameter	Unit	Symbol	Level1	Level 2	Level 3
1	Voltage	Volt	V	0	5	10
2	Molal Concentration	No.(micron)	M	0	0.25	0.5
3	Diameter of rod	mm	D	3.5	4.5	5.5
4	Number of cycle	……….	N	3	6	9

Table 2: Constant process parameters and their value

Sr. No.	Process Parameters	Range	Unit
1	Abrasive size	150	micron
2	Extrusion pressure	6	N/mm2
3	Shape of CFG rod	Triangular	------
4	Initial surface Ra	3.25-3.75	µm
5	Media flow volume	290	cm3

6	Fixture material	Nylon	-------
7	Polymer-Gel ratio	1:1	% by weight
8	Temp. of media	24 ± 2	°C
9	Reduction Ratio	0.95	-----
10	Work piece Material	Gun metal	-----

4. EXPERIMENTAL RESULTS

Experimental design was prepared using L9 orthogonal array based upon taguchi technique. Total 27 experiments were carried out. The experimental output are shown in table 3.

Table 3: Orthogonal Array L9 with S/N and Raw data of Various Response Characteristics

S No.	V	M	D	N	R1	R2	R3	S/N	Raw
1	0	0	3.5	3	4.2	4.11	3.96	12.22	4.09
2	0	0.25	4.5	6	6.1	6.12	6.08	15.70	6.1
3	0	0.5	5.5	9	3.2	3.19	3.2	10.09	3.2
4	5	0	5.5	6	5.9	5.91	5.92	15.43	5.92
5	5	0.25	3.5	9	5.45	5.44	5.41	14.70	5.41
6	5	0.5	4.5	3	3.1	3.2	3.25	10.05	3.25
7	10	0	4.5	9	7.12	7.25	7.02	17.05	7.02
8	10	0.25	5.5	3	6.47	6.45	6.49	16.21	6.49
9	10	0.5	3.5	6	6.12	6.05	6.08	15.68	6.08

Thepercentage change in surface roughness (Ra) for S/N ratio & raw data at three levels L1, L2, L3 for each parameter shown in table 4.

Table 4: Main Effect (S/N & Raw data)

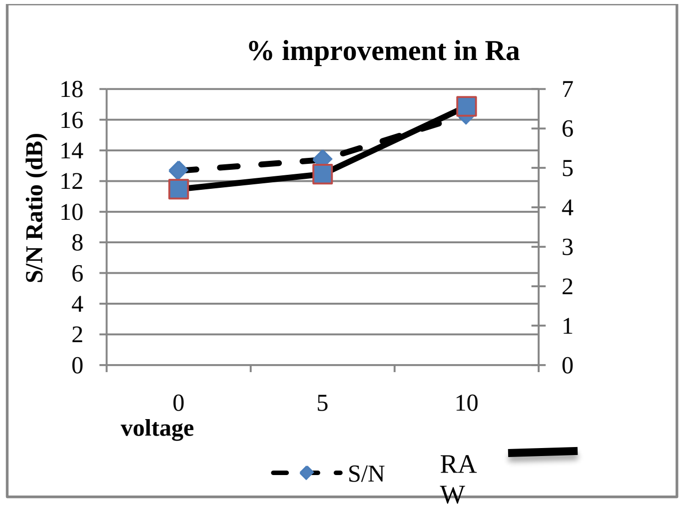
LEVEL	V		M		D		N	
	S/N data	Raw data	S/N data	Raw data	S/N data	Raw data	S/N data	Raw data
L1	12.68	4.46	14.91	5.71	14.20	5.20	12.83	4.58
L2	13.40	4.84	15.54	6.00	14.27	5.47	16.61	6.03
L3	16.32	6.56	11.94	4.15	13.91	5.19	13.95	5.25
L2-L1	0.72	0.38	0.64	0.29	0.07	0.27	0.55	1.45
L3-L2	2.92	1.72	-4.23	-1.85	-0.36	-0.28	1.51	-078

Where L1, L2 and L3 denotes the value of S/n & raw data at levels 1,2 & 3 of parameters.L2-L1 is the effect occurs when the particular parameter value changes from level 1 to level 2. L3-L2 is the effect occurs when the same parameter value changes from level 2 to level 3.

5. DISCUSSION

5.1 Voltage

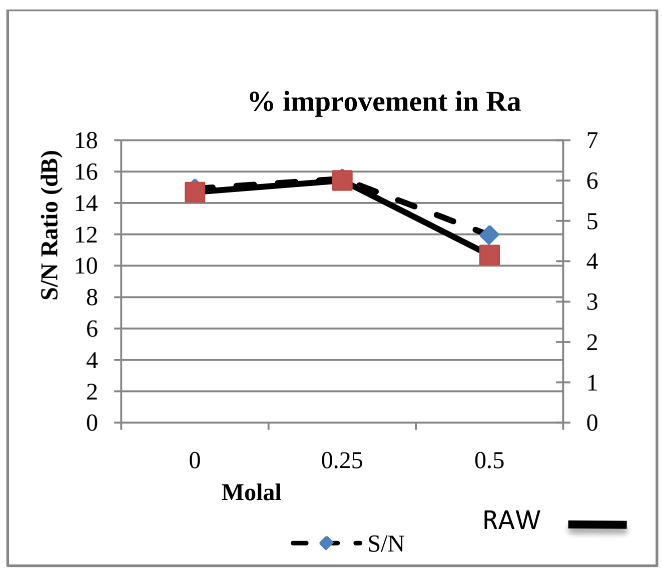
From the graph (a) it was noted that as the votage is applied,percentage change in surface roughness (Ra) increases.Initially metal removal occurs due to abrasive cutting action only, but When we applied the voltage,the enhance machining takes place due to combination of electrolytic dissolution at the anode(workpiece) and abrasive media. The material removal occurs due to eletrochemical machining was carried out by abrasive media.The surface becomes soft as the hard surface is eroded by electrochemical and abrasive attacks which removes material from peaks at more extent as compared to simple abrasive flow finishing or electrochemical process.



(a) Effect of voltage on S/N data & RAW data

5.2 Molal Concentration

As the concentration of molal in the abrasive media increases, it increases the number of ions available for electrochemical attack at anode(workpiece).But beyond a certain limit,

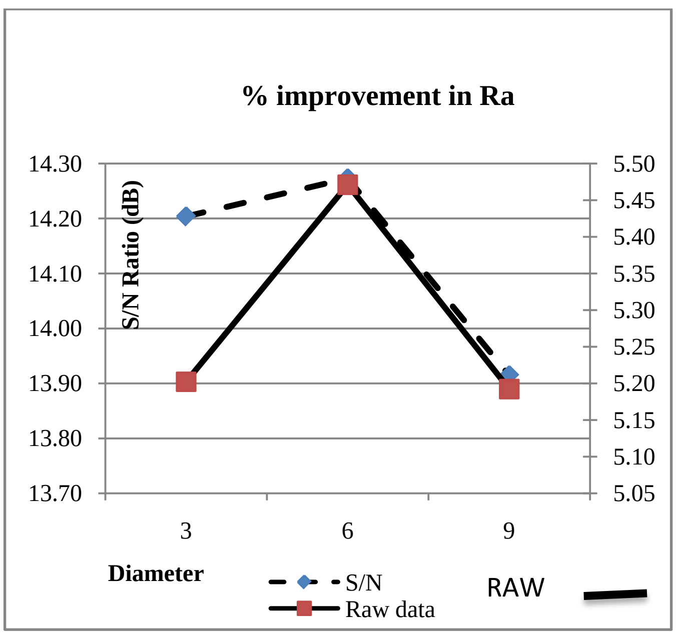


(b) Effect of molal concentrtion on S/N data & RAW data

it decreasess the viscosity of abrasive medium by reacting abrasive media and affects the material removal rate from the workpiece.So as molal concentration increases in abrasive media, it reduces the percentage change in surface roughness.So for better results, its concentration should be maintained otherwise if molal concentration increses beyond a certain limit,it reduces the viscosity of abrsive media at a greater extent and lower the material removal and hence surface roughness.

5.3 Diameter of Rod

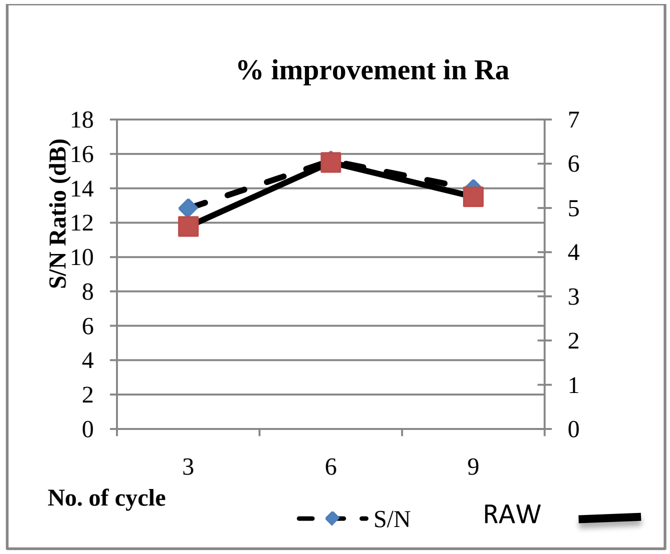
As the diameter of rod inside the workpiece increases,it reduces the gap between the inner surface of workpiece and rod. So cross-sectional area through which medium was flowing reducesand resistance to flow of medium increases. It raises the magnitude of normal force acting by abrasive on inner surface of workpiece and more material removal occurs from edge and peaks. But as this gab decreases beyond a limit,abrasive start producing indent and scratches on inner surface.So quality of inner surface decreases.



(c)Effect of diameter of rod on S/N data & RAW data

5.4 Number Of Cycle

When the piston moves vertically upwards and downwards, it constitute a cycle. It was noted that as number of cycle increases from 3 to 9, in each cycle abrasive strikes on workpiece and also ECM. So after repeated movement of abrasive through workpiece, more and more material was removed by combination of electrochemical process and abrasive flow process, which results in better finishing of workpiece.



(d) Effect of Number of cycle on S/N data & RAW data

6. ANALYSIS

After the experimental work calculation, Pooled ANOVA was performed for analysis of result and F-test was performed to find out the most significant parameter. From the table, it was depicted that all the parameters have a significant effects on surface roughness. It is clear from the graph that percentage change in surface roughness is highest at third level of voltage, second level of molal, second level of diameter of CFG rod and second level of number of cycle.

Table 5: Pooled ANOVA S/N Data

Source	SS	DOF	V	P	SS'	F-Ratio
Voltage	22.35	2	11.18	36.64	22.13	101.61
Molal	22.14	2	11.07	39.25	21.92	100.62
Diameter of rod	Pooled					
No. of cycle	11.69	2	5.85	20.73	11.47	53.14
Error	0.22	2	0.11	0.39	22.79	
Total	56.40	8		100.01	56.40	

SS- Sum of square, DOF-degree of freedom, V-variance, SS'-pure sum of square. *Significant at 95% confidence level, Fcritical = 19

Table 6: ANOVA Raw Data

Source	SS	DOF	V	P	F-Ratio
voltage	22.51	2	11.26	44.79	2780.65
Molal	17.74	2	8.87	35.31	2191.62
Diameter of rod	0.45	2	0.23	0.90	55.65
No. of Cycle	9.48	2	4.74	18.86	1170.65

Error	0.07	18	0.00	0.00	
Total	50.26	26		99.86	

SS- Sum of square, DOF-degree of freedom, V-variance, SS'-pure sum of square. *Significant at 95% confidence level, Fcritical = 3.4928.

7. CONCLUSION

The following conclusion was noticed from the results:

a. It is clear from this research that electrochemical process combination with simple abrasive flow finishing process have a major impact on surface roughness. Better results can be obtained by clubbing more process like magnetic and electrochemical together assist with simple AFF.

b. The contribution of Voltage is (36.64%) for S/N data and (44.79%) for raw data. Molal concentration is (35.31%) for raw data and (39.25%) for S/N data. The optimal parameter for effective material removal was observed as V3M1D3N3.

c. The dominant parameter was found to be voltage and molal concentration. More parameters can be varied at different level by considering interaction between these parameters and by adopting more complex experimental design based on taguchi methodology.

REFERENCES

[1] Dabrowski, L., Marciniak, M. & Szewczyk, T., "Analysis of abrasive flow machining with an electrochemical process aid", Proc. IMechE Part B: J. Engineering Manufacture, 2006,Volume 220, pp. 397- 403.

[2] B.S. Brar, R.S. Walia, V.P. Singh, "Electro Chemical aid to Abrasive Flow Machining Processe: Hardness for improved Surface Finishing", International Conference on Advancements and Futuristic Trends in Mechanical and Materials Engineering (October 5-7, 2012).

[3] Ravi Sankar M., Mondal S., Ramkumar J., Jain V.K., Experimental Investigations and Modelling of Drill Bit Guided Abrasive Flow Finishing (DBG-AFF) Process, International Journal of Advanced Manufacturing Technology 42 (2009) 678-688.

[4] Walia, R.S.; Shan, H.S.; Kumar, P. Parametric optimization of centrifugal force assisted abrasive flow machining by the Taguchi Method. Journal of Materials and Manufacturing Processes 2005, 21 (4) (in press).

[5] Singh, S. (2002) — Studies in Metal Finishing with Magnetically Assisted Abrasive Flow machining. Ph.D thesis, Mechanical and Industrial Engg Dept., IIT Roorkee (India)

[6] Jones, A. R. and Hull, J. B. (1998) Ultrasonic flow polishing. Ultrasonics 36 , pp. 97-101

[7] H S Mali and Dr A Manna;" An Experimental Investigation on Abrasive Flow Finishing of Al-6063 Alloy Cylindrical Surface."IE (I) Journal–PR (2009), volume 90, pp 3-6

[8] Manas Das, V.K. Jain and P.S. Ghoshdastidar, "Fluid flow analysis of magnetorheological abrasive flow finishing (MRAFF) process" , International Journal of Machine Tools and Manufacture, Volume 48, Issues 3-4, March 2008, Pages 415-426

[9] P.Ghose, Polymer Science and Technology of Plastics and Rubbers, Tata McGraw Hill, New Delhi, 2000

[10] Jain V.K; Adsul. S.G; "Experimental investigations into abrasive flow machining "International Journal of Machine tool and Manufacturing,40,2002,1003-1021

[11] Loveless T.R,Williams R.E and Rajurkar K.P;"A study of the effects of Abrasive Flow finishing on various machined surfaces. Journal Material processing technology,47,1994,133-151

[12] K. Przyklenk, A process for surface finishing & deburring of the work piece with a complicated shape by means of an abrasive laden medium, ASME, Newyork, PED, 1986 vol 2 pp 101-110.

[13] Williams R.E., Rajurkar K.P., Stochastic modeling and analysis of abrasive flow machining, Transaction ASME, Journal of Engineering for Industry, 114, (1992), 74-81.

[14] Petri, K. L., R. E. Billo, and B. Bidanda, "Modeling the Abrasive Flow Machining Process: A Neural Network Approach," 4th Industrial Engineering Research Conference Proceedings, Nashville, Tennessee, (IIE), 239-244 (1995).